Description

Method and Device for Gas Recovery

This invention relates to a method for recovering gas from a process that operates with gas under pressure, for which gas is sent from a high-pressure container to a closed chamber in which the process takes place, where the gas to be recovered is compressed in multiple compression stages and fed back into the high-pressure container.

Furthermore, this invention relates to a device for recovering gas from a process operating with gas under pressure, said process removing the gas from a high-pressure container and taking place in a closed chamber.

Gases under pressure are needed for a variety of processes. Examples that can be given here include processes in heat treatment, special processes in thermal spraying or laser welding. Recovery of gases in processes in which the gas is under a high pressure is particularly important because the quantities of gas used are very large and consequently, economical operation of this process is possible only if the gas is carried in circulation.

For example, the quenching process in the heat treatment of metallic workpieces constitutes a decisive work step. It is important here for the workpieces to be cooled very rapidly and uniformly to prevent unwanted changes in the material such as phase transitions or fine cracks which occur when the workpiece is cooled slowly and irregularly. Consequently, in quenching it is of crucial importance for a large quantity of gas to flow very rapidly into a quenching chamber where a high pressure is built up. The quenching process proceeds as follows in practice: when the workpiece is ready in the quenching chamber, a valve between the high-pressure container and the quenching chamber is opened and the gas flows suddenly from the high pressure reservoir into the quenching chamber. The pressure in the quenching chamber then rises to approximately 20 bar, while the pressure in the high-pressure reservoir drops from the starting pressure, which is

approximately 30 bar, to approximately 22 bar. After quenching, a valve is opened to release the gas from the quenching chamber. If the pressure in the quenching chamber has dropped to ambient pressure, the quenching chamber is opened and the workpiece is removed. A suitable closed container or a closed chamber into which the workpiece is introduced or the heat treatment itself may be used as the quenching chamber. Instead of a workpiece, a batch of workpieces may also be quenched.

It is advisable economically and technically to send the spent gas to a circulation system because the resulting quantities of gas are very large. Gas recovery is normally performed with the help of a gas buffer. To do so, the quenching chamber is emptied into a gas buffer until the pressure is equalized in the quenching chamber and the gas buffer. The gas buffer is generally a balloon and/or a pressure container. The balloon expands when filled. Since the gas is ultimately under atmospheric pressure in the balloon, the gas takes up a large volume and the filled balloon requires a great deal of space accordingly. Before the gas is fed back into the high-pressure container, it must be compressed from atmospheric pressure to the pressure prevailing in the high-pressure reservoir. Since a single-stage compressor is unable to bridge such an enormous difference in pressure, a multistage compressor is used for this purpose. In a multistage compressor, several compressors are connected in series. The bottom stage compresses the gas from the output pressure to a higher pressure. From this pressure, the next stage in turn raises the pressure level to a higher stage. There may be as many stages as desired before finally reaching the end pressure prevailing in the high-pressure container by the end stage. The great energy loss which occurs due to the fact that the gas is depressurized in each quenching operation first from the high pressure of the chamber to the low pressure in the gas buffer and then is compressed again to the high pressure of the high pressure chamber is a disadvantage of this method.

The object of this invention is to provide a method which will avoid these disadvantages of the known method and which will send

preferably all the gas quantity available at ambient pressure to the gas recovery system.

This object is achieved according to this invention by compressing the gas directly from the pressure prevailing in the chamber, at least one additional compression stage being used when the pressure in the chamber falls below a limit level. According to this invention, gas is removed from the chamber until the pressure in the chamber reaches the limit value of the intake pressure. The limit value of the intake pressure is determined by the design of the compression stage because for each compressor there is a minimum intake pressure up to which the compressor is able to compress the gas to the required pressure and below which compression is no longer possible. Since the chamber has been evacuated to the respective limit pressure with one compression stage, according to this invention another compression stage is added. With this second compression stage, it is possible to remove the gas from the chamber at the lower pressure and compress it in the subsequent stage. Thus with the inventive method, the pressure level prevailing in the chamber at any given time is utilized appropriately. Since a very high pressure prevails in the chamber mainly at the start of removal of the gas, this pressure often being only slightly below the pressure of the high-pressure container and dropping with removal of the gas but still being far above atmospheric pressure and only slowly approaching the latter, therefore only the pressure difference prevailing between the chamber and the high-pressure container at that moment need be overcome with the inventive method. Compression time is shortened considerably because consequently now only a very small amount of the gas must overcome a great pressure difference and the energy demand required for compression is also drastically reduced—in comparison with compression from atmospheric pressure. Compression starting from atmospheric pressure is necessary with the method previously customary in which the gas is depressurized into a gas buffer. The fact that this gas buffer is omitted in the inventive method is a great advantage because the gas buffer takes up a large space due to the large volume of the gas under atmospheric pressure. This is advantageous not only in the case of tight spatial

conditions but also the space savings have an economically advantageous effect. Furthermore, the inventive method is characterized by a low investment cost.

The problem of emptying a closed gas chamber having a high gas pressure and having to feed this gas into a container at a high pressure, however, does not occur only in recovery of gases but also occurs in plant engineering. With this invention it is now possible to utilize the high pressure of the chamber and to convey the gas into a container in which the prevailing pressure is above the initial output pressure of the chamber. The inventive procedure can be used in all cases in which such a situation occurs.

Advantageously, a multistage compressor or several compressors connected in series are used. Two or three compression stages are sufficient here to particular advantage to bridge the entire pressure range from atmospheric pressure at the end of the evacuation process up to the pressure of the high-pressure container.

In an advantageous embodiment of this invention, the individual compression stages are fed directly into the chamber according to the declining emptying pressure of the chamber. In compression of the gas, the compression stages (n stages) are run through successively, the gas being removed from the chamber at the lowest compression stage (first stage) and being fed into the high-pressure container with the highest compression stage (n-th stage). At the start of evacuation, only one compression stage (n-th stage) is used. This withdraws the gas from the chamber, compresses it and feeds it into the high-pressure container. In doing so, the pressure in the chamber drops. Then according to this invention, when the pressure drops below the limit value of the highest stage (n-th stage), the next lower stage ((n - 1)-th stage) is added. This stage then withdraws the gas from the chamber and compresses it to an intermediate pressure which in general corresponds to the intake pressure of the highest stage (n-th stage). Then from the intermediate pressure the gas is compressed in the highest stage to the final pressure and fed into the high-pressure container. The pressure in the chamber continues to drop as the withdrawal is continued, reaching the

cut-off pressure to which the (n - 1)-th compression stage operates. An (n - 2)-th compression stage is then added. This is the lowest compression stage at which withdrawal and compression take place at the lowest pressure level. The (n - 1)-th compression stage compresses the gas to the next higher pressure level and finally the end pressure is reached with the n-th and highest stage. The pressure differences that are overcome with the individual stages often vary and are determined by the properties of the compressor in the particular compression stage. For compression to the required end pressure, any number of stages n may be run through. The individual compression stages are then either different compressors connected in series or the individual stages of a multistage compressor. The various compressors and/or the different compression stages are used according to the inventive sequence.

In an embodiment of this invention, the individual compression stages have different compression capacities. It is particularly advantageous here that the gas in the highest compression stage (n-th stage) with which this gas is compressed with the highest compression capacity of the individual compression stages before any other additional stage, i.e., (n - 1)-th stage is added. This may be accomplished through appropriate dimensioning of this compressor or through a parallel circuit of multiple compressors. A high compression output in the highest compression stage greatly reduces the time required for compression because in particular at the beginning of withdrawal large quantities of gas are generated.

In an embodiment of this invention, the pressure in the chamber at the beginning is between 6 and 60 bar and the pressure in the high-pressure chamber is between 8 and 62 bar. Thus the quenching pressures conventional in the heat treatment in the quenching chamber are also between 6 and 60 bar.

It is also particularly advantageous that the inventive method is used for recovery nitrogen, argon or helium and mixtures thereof. In the heat treatment, quenching is often performed with nitrogen. Therefore, the inventive method has been designed for recovery of

nitrogen with particular advantages. However, recovery of other quenching gases, e.g., argon or helium as well as mixtures of nitrogen, argon and helium is also possible to advantage. Since the inventive method is characterized by a low investment cost, it also permits economical recovery of relatively inexpensive gases such as nitrogen. When expensive gases or gas mixtures which have previously also been sent for recovery are used for quenching, the inventive method makes the recovery much less expensive.

This object is achieved for this device according to this invention by the fact that the chamber communicates with at least two compressors that are connected in series and form at least two compression stages or with each compression stage of a multistage compressor communicates via connecting lines directly without an intermediate reservoir, whereby the connecting lines include opening and closing overcurrent regulators or cut-off elements which are connected to a switch unit that controls the cut-off elements and whereby the highest compression stage (n-th stage) of the compressors connected in series or of the multistage compressor communicates with the high-pressure container. With the inventive device it is thus possible in a multistage compressor to separately supply the individual compression stage responsible for different pressure ranges or the different compressors which form a multistage compressor through a series connection. It is thus possible to use the respective compression stage according to its design with respect to the pressure range. The lines lead between the stages according to this invention and carry the gas to the next higher compression stages. The gas does not reach them until after compression in this stage. If there is no higher stage, the gas enters the high-pressure container. Overcurrent regulator or cut-off elements cut off the lines leading to the lower compression stages and cause the gas to be sent to higher compression stages. Overcurrent regulators are mechanical regulators which determine the pressure prevailing upstream from the valve and open or close according to this pressure. However, the switching unit assumes control of the cut-off elements. The switching unit preferably includes a pressure sensor for determining the pressure in the chamber. If the

pressure in the chamber drops below the specific limit value for the particular compression stage, the overcurrent regulators then open and close in such a way and/or the switching unit sets the cut-off elements in such a way that another lower compression stage assumes the role of compression in the pressure range below that of the previous compression stage, and the previous stage recompresses the gas coming from the lower stage. On evacuation of the chamber, consequently the highest compression stage (n-th stage) performs the compression first, then the switch unit switches the next lower compression stage ((n - 1)-th stage) and so far until all the compression stages are in operation. Consequently with the inventive device it is not necessary to depressurize the gas of the chamber into a gas buffer and to use all the stages according to their sequence for the total quantity of gas. Saving by eliminating the gas buffer means enormous savings in terms of space.

In an advantageous embodiment, the switching device is connected to a pressure sensor situated on the chamber.

Advantageously one or more compression stages include multiple compressors connected in parallel because the compression performance of one stage is increased by the parallel switching. However, the compression performance of a compression stage is also increased through appropriate dimensioning.

The inventive method and device are used to particular advantage in the quenching process in heat treatment.

The inventive method will now be described in greater detail in two variants as examples on the basis of the schematic diagrams according to FIG 1 and FIG 2.

FIG 1 shows a high-pressure container 1, a quenching chamber 2 provided for a heat treatment, compressors 3, 4, cut-off elements 5, 6, 7, a switching unit 8 having a pressure sensor 9, lines 10, 11 and a gas supply 12. The workpieces are in the quenching chamber 2 for a quenching process. In the high-pressure container 1 which is filled

with nitrogen, for example, a pressure p1 of 30 bar prevails. When the valve 5 is opened, gas suddenly flows out of the high-pressure container 1 into the quenching chamber 2. Then the pressure in the high-pressure container drops from 30 bar to 22 bar and the pressure in the quenching chamber rises to 20 bar. Then the cut-off element 5, which is designed as a valve like the other cut-off elements is closed. Now the cooling of the workpieces may be accomplished by means of the quenching gas which is carried in circulation. After cooling, the gas is recovered from the quenching chamber. To do so, first the valve 6 is opened while the valve 7 remains closed. The gas flows through the line 10 into the compressor 4 which forms the compression stage and is compressed there to 30 bar and sent into the high-pressure container 1. When the gas is removed from the quenching chamber 2, the pressure p2 in the quenching chamber consequently drops. Then when the pressure in the quenching chamber 2 drops below the limit value, which is 6 bar, for example, for the compressor 4, the valve 6 is closed and the cut-off element 7 is opened. The gas then goes through the line 11 into the compressor 3 which forms the (n - 1)-th compression stage and from there goes further into the compressor 4 which forms the n-th compression stage. The direct path to the compressor 4 via the line 10, however, is blocked by the cut-off element 6. The control of the cut-off elements is assumed by the switching unit 8. Therefore the pressure sensor 9 which measures the pressure p2 in the quenching chamber is assigned to the switching unit 8. Then if the cut-off pressure is determined by this pressure sensor in the quenching chamber 2, the switching unit 8 performs the switching operation. Consequently the gas is first compressed to 6 bar, for example, in the compressor 3 before being compressed to 30 bar in the compressor 4 and fed into the high-pressure container 1. The gas supply 8 is needed to increase circulation during operation and to compensate for gas losses.

FIG 2 shows another advantageous embodiment of the inventive method. The reference notation which is the same as that in FIG 1 denotes the same element. In addition there are overcurrent regulators 12, 13 and a valve 14. To recover gas after the quenching process in the quenching chamber 2, first the valve 14 is opened. The overcurrent

regulator 13 which is mounted in the connecting line 11 is closed at the beginning of the recovery while the overcurrent regulator 12 of the connecting line 10 is open. The gas goes from the quenching chamber 2 through the connecting line 10 into the compressor 4 and is compressed by the compressor 4 to the pressure p1 of the high-pressure container 1 and is fed into the latter. In doing so, the pressure p2 in the quenching chamber 2 drops. The compressor 4 thus forms the n-th compression stage. When the pressure p2 in the quenching chamber 2 drops below the minimum intake pressure of the n-th compression stage, the overcurrent regulator 12 closes and the overcurrent regulator 13 opens. The gas then goes from the quenching chamber into the compressor 3 where it is compressed to the intake pressure of the compressor 4. Then it is compressed by the compressor 4 to the pressure p1 of the high-pressure container and fed into the high-pressure container 1. Consequently the gas is compressed first from the (n - 1)-th compression stage without intermediate storage from the quenching chamber and from the pressure p2 prevailing in the quenching chamber and then is compressed from the n-th compression stage to the pressure p1 of the high-pressure container.

The inventive method may be used for example in hardening tools made of steel.